REMARKS

Further and favorable reconsideration is respectfully requested in view of the foregoing amendments and following remarks.

Thus, the specification has been amended, on pages 8 and 9, to insert reference number 52 for the mixed conducting membrane, which is in response to the objection to the disclosure, rendering the objection moot.

Other minor changes, of an editorial nature, have also been made in the specification.

Claim 2 has been amended in response to the objection to this claim, by deleting reference to the non-catalytic combuster, rendering the objection moot. As a result, new claim 12, directed to the non-catalytic combuster, has been added to the application.

Claims 1, 3, 5 and 7-11 have been amended in response to the rejections of these claims under 35 U.S.C. §112 and 35 U.S.C. §101, rendering the rejections moot, with one exception to be discussed below.

Attached hereto is a marked-up version of the changes made to the specification and claims 1-3, 5, and 7-11 by the current amendment. The attached pages are captioned "**Version with markings to show changes made.**"

The exception referred to above is the rejection of claim 1 under the second paragraph of 35 U.S.C. §112 based on the term "sufficiently high", which is respectfully traversed. Applicants note that this term in claim 1 is followed by the functional language "to be used as oxidant in the combuster in the second stage". That is, according to (d) in claim 1, the concentration of oxygen in the sweep gas of step (c) is increased to a level which is high enough to use the sweep gas as oxidant in the combuster in the second stage. Applicants respectfully submit that the use of this functional language provides the requisite degree of certainty of the scope of the invention.

The patentability of the present invention over the disclosures of the references relied upon by the Examiner in rejecting the claims will be apparent upon consideration of the following remarks.

Thus, the rejection of claims 1-5 under 35 U.S.C. §102(e) as being anticipated by Prasad et al. '272, as well as the rejection of claim 6 under 35 U.S.C. §103(a) as being unpatentable over this reference, are respectfully traversed.

Initially, Applicants note that, according to the International Search Report of record, the Prasad et al. '272 reference is a family member of EP 0882486 cited in the International Search Report; and Applicants further note that the International Preliminary Examination Report relies on documents other than EP '486 in discussing the pertinence of the cited prior art. This fact tends to support Applicants' position, which will be discussed below, that the subject matter of the claims is patentable over Prasad et al. '272.

Thus, in general, the object of Prasad et al. '272 was to provide an efficient integrated process for oxygen-enhanced combustion, while the object of the present invention was to arrive at an energy efficient method to recover substantially all CO_2 generated in a combustion process. This difference is clearly shown in that the oxygen depleted air stream and the CO_2 containing stream in most cases in Prasad et al. '272 are mixed downstream the membrane. In this case it will not be possible to recover CO_2 in an efficient way. Otherwise, if the two streams are not mixed, the result would produce a nitrogen-enhanced gas stream and not CO_2.

Prasad et al. '272 also claims that the gas stream exiting the permeate side of the ion transport module has an oxygen concentration of about 10% to about 90%, whereas in the staged process of the present invention it is acceptable to keep the oxygen concentration below 10%.

The present state of the art techniques as disclosed in Prasad et al. '272 use large amounts of recirculated exhaust gas to purge the permeate side of the membrane. The present invention, however, will reduce the required amount of purge (or sweep gas) gas significantly. This is obtained by using several stages where each stage includes a membrane, a combuster and a combustion chamber. Application of e.g. 10 stages may reduce the amount of sweep gas with about 95% compared with a single stage process as disclosed in Prasad et al. '272. This has the following advantages:

1. The staged process can operate at a low (<10%) concentration of oxygen in the oxygen-enriched sweep gas, improving the driving force for oxygen transport through the membrane. This will reduce the membrane area and thus the costs.

2. The amount of sweep gas (or recirculated combustion gas) is significantly reduced. If exhaust gas is recycled, a blower or a compressor device is needed to circulate the purge gas (i.e.

to overcome the pressure drop in the cycle). Due to the high temperature of recycled gas (400 - 1100°C) this compressor device could be very expensive and the energy requirement to recycle the gas could for the same reason be rather high. By reducing the amount of gas both the cost and energy requirement will be significantly reduced.

For these reasons, Applicants take the position that the presently claimed invention is patentable over the Prasad et al. '272 reference.

The rejection of claim 7 under 35 U.S.C. §103(a) as being unpatentable over Prasad et al. '272 in view of Prasad et al. '223 is respectfully traversed.

The comments set forth above, concerning the Prasad et al. '272 reference are considered to be equally applicable to this rejection.

With regard to the Prasad et al. '223 reference, one of its objects is to recover carbon dioxide as a co-product, but the method or techniques differ significantly from the method of the present invention in that the reference method includes two membrane sections (or two membrane zones) where a fuel is added to the first membrane section such that heat is generated by a reaction within the permeate zone in order to heat the feed gas stream. The heated (oxygen containing) feed gas stream then enters the second section where oxygen is recovered. In the present invention the fuel is added to a separate combustion chamber and does not use the technique disclosed in Prasad et al. '223. Fuel is not added directly to the membrane section.

Also, Prasad et al. '223 describes no multiple stages, while multiple stages is the main objective of the present invention as mentioned above.

Furthermore, as indicated above, the main object of Prasad et al. '272 is production of enriched oxygen streams with a rather high concentration of oxygen (10-90%). Use of multiple steps with combustion and heating of air has no advantage in this case. The advantages of the staged technique, however, are air production of a gas stream with a low concentration of oxygen to avoid excessive heat generation in the combustion sections and to improve the driving force for oxygen transport. The driving force for oxygen transport through the membrane decreases with increased oxygen concentration in the sweep gas. In Prasad et al. '223 a different technique is used with

combustion of fuel within the membrane unit. Combustion, oxygen transport and heat transfer are combined in one unit. The staged technique has no relevance in this case.

For these reasons, Applicants take the position that the presently claimed invention is clearly patentable over the applied references.

Therefore, in view of the foregoing amendments and remarks, it is submitted that each of the grounds of objection and rejection set forth by the Examiner has been overcome, and that the application is in condition for allowance. Such allowance is solicited.

Respectfully submitted,

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March 31, 2003

1) to pick up oxygen transported through said membrane 3. The mixture of sweep gas and oxygen is fed to a catalytic or non-catalytic burner 5 where a fuel 6 is combusted. Hot exhaust gas 7 is fed to a heat exchanger 8 where compressed air 33 is heated. Partially cooled exhaust gas 9 is used as sweep gas on the permeate side 10 of a second MCM 11 (stage 2). Oxygen containing gas 12 is mixed with a fuel 13 in a catalytic or non-catalytic burner 14 to generate a hot exhaust gas 15. Hot exhaust gas 15 with increased amount of CO_2 and H_2O is fed to heat exchanger 16 to heat compressed air 34. Partially cooled exhaust gas 17 is used as sweep gas in a next MCM stage (not shown). The number of required MCM-stages depends on the amount of sweep gas fed to the first MCM-stage. A hot exhaust gas with increased amount of CO_2 and H_2O is used as sweep gas on the permeate side of the last MCM stage 19. Oxygen containing sweep gas 20 is mixed with a fuel 21 in a catalytic or non-catalytic burner 22 to generate a hot exhaust gas 23. This CO_2containing exhaust gas is heat exchanged with compressed air 35 and the CO_2-containing exhaust gas 24 is further depressurized in turbine generator 25 to generate power. Depressurized exhaust gas 26 is fed to heat recovery system 27 to produce steam and condensate water 30. High concentrated CO_2 is recovered and fed to a CO_2 injection system 29.

19 Air 31 at ambient conditions is fed to compressor 32. Compressed air 33 is further heated in heat exchanger 8 and 16 and further in several stages (not shown) including the last heat exchanger 36. Heated air 37 is fed to the retentate side of MCM 19 and further through several MCM stages including MCM 11 and MCM 3. Partly oxygen depleted air 46 is depressurised in turbine generator 47 to generate power or is fed to a mixed conducting membrane 52 capable of producing pure oxygen or synthesis gas. Depressurised oxygen depleted air 48 is fed to heat recovery system 49 and the cooled gas 50 is discharged off.

20 Figure 2 shows a combined power and heat generating process comprising application of a staged Mixed Conducting Membrane (MCM) process where a sweep gas 1 is fed to the permeate side 2 of a first stage MCM 3 to pick up oxygen transported through said membrane 3. The mixture of sweep gas and oxygen is fed to a catalytic or non-catalytic burner 5 where a fuel 6 is combusted.

Hot exhaust gas 7 is fed to heat exchanger 8 where compressed air is heated. Partially cooled exhaust gas 9 is used as sweep gas on the permeate side 10 of a second MCM 11 (stage 2). Oxygen containing gas 12 is mixed with a fuel 13 in a catalytic or non-catalytic burner 14 to generate a hot exhaust gas 15. Hot exhaust gas 15 with increased amount of CO_2 and H_2O is fed to heat exchanger 16 to heat compressed air. Partially cooled exhaust gas 17 is used as sweep gas in a next MCM stage (not shown). The number of required MCM-stages depends on the amount of sweep gas fed to MCM-stage one. A hot exhaust gas with increased amount of CO_2 and H_2O is used as sweep gas on the permeate side of a last MCM stage 19. Oxygen containing sweep gas 20 is mixed with a fuel 21 in a catalytic or non-catalytic burner 22 to generate a hot exhaust gas 23. This -CO_2containing exhaust gas is heat exchanged with compressed air 35 and the gas 24 is further depressurized in turbine generator 25 to generate power. Depressurized exhaust gas 26 is fed to heat recovery system 27 to produce steam and condensate water 30. High concentrated CO_2 is recovered and fed to a CO_2 injection system 29.

Air 31 at ambient conditions is fed to compressor 32. Compressed air 33 is further divided into several air streams equal the number of MCM stages. Compressed air stream 35 is heated in heat exchanger 36 and the hot air stream 37 is fed to the retentate side of MCM 19. Oxygen depleted air 38 is fed to mixer 45. Compressed air stream 39 is heated in heat exchanger 16 and the hot air stream 40 is fed to the retentate side of MCM 11. Oxygen depleted air 41 is fed to mixer 45. Compressed air stream 42 is heated in heat exchanger 8 and the hot air stream 43 is fed to the retentate side of MCM 3. Oxygen depleted air 44 is fed to mixer 45. The remaining air streams from separator 51 is fed to the remaining heat exchanger and MCM-stages (not shown) and the resulting hot oxygen depleted air streams is collected in mixer 45. Oxygen depleted air 46 is depressurised in turbine generator 47 to generate power or is fed to a mixed conducting membrane 52 capable of producing pure oxygen or synthesis gas. Depressurised oxygen depleted air 48 is fed to heat recovery system 49 and the cooled gas 50 is discharged.

pure oxygen or synthesis gas. Depressurised oxygen depleted air 48 is fed to heat recovery system 49 and the cooled nitrogen-containing gas 50 is discharged.

An alternative configuration of the process acording to figure 1 and 2, comprises that the CO_2 containing gas stream 24 is mixed with a fuel and fed to a catalytic burner in order to remove oxygen. The amount of fuel is regulated such that the concentration of oxygen is reduced to below 50 to 100 ppm. The CO_2 containing exhaust gas with a low concentration of oxygen is depressurised in turbine generator 25 to generate power and heat is further recovered in 27. The CO_2-containing gas after recompression and drying may be injected for enhanced oil recovery.

An alternative configuration of the process according to figure 1 and 2, comprises that the CO_2 containing gas stream 24 is mixed with a fuel and fed to a combined mixed conducting membrane and partial oxidation reactor as described in patent application NO-A-972631 (published 06.12.98) in order to reduce the concentration of oxygen to below 10 ppm. The CO_2 containing exhaust gas with a low concentration of oxygen is depressurised in turbine generator 25 to generate power and heat is further recovered in 27. The -CO_2 containing gas after recompression and drying may be injected for enhanced gas and ~~oul~~ oil recovery.

An alternative configuration of the process according to figure 1 and 2, comprises that the CO_2 containing gas stream 23 is depressurised in turbine 25 without heatexchanging with air in heat exchanger 36.

Fuel useful in the processes described in example 1 and 2 comprises natural gas, methanol, synthesis gas comprising hydrogen and carbon monoxide, refinery fuel gas containing mixed hydrocarbons or other combustible mixtures.

By the present invention the inventors has arrived at an efficient method to recover substantially all CO_2 generated in a combustion process.

CLAIMS

(amended)

1. A method for recovering substantially all carbon dioxide generated in a combustion process,

characterised in that

the method comprises the following steps:

a) a sweep gas is used to pick up oxygen on the permeate side of a mixed conducting membrane in a first stage which is capable of separating oxygen from a ~~hot~~ pre-heated air stream fed to the retentate side of the membrane

b) the sweep gas containing oxygen is applied as oxidant in a combuster in the first stage where a carbon containing fuel is combusted

c) ~~hot~~ pre-heated combustion products of step b) containing CO_2, H_2O and a low concentration of O_2 is used as sweep gas in a membrane in a second stage downstream the combuster in step b)

d) the concentration of oxygen in the sweep gas of step c) is increased in the membrane in the second stage (step c) to a sufficiently high level to be used as oxidant in the combuster in the second stage

e) and the steps c) - d) are repeated in one or more stages.

(Amended)

2. A method for recovering substantially all carbon dioxide generated in a combustion process according to claim 1,

characterised in that

the combuster is a catalytic ~~or non catalytic~~ combuster.

(amended)

3. A method for recovering substantially all carbon dioxide generated in a combustion process according to claim 1,

characterised in that

the sweep gas used in step a) is ~~not~~ superheated steam or a mixture of steam and/or recycled exhaust gas from the last combuster in the sequence.

4. A method for recovering substantially all carbon dioxide generated in a combustion process according to claim 1,
characterised in that
the mixed conducting membrane is made from materials with both ionic and electronic conductivity.

(Amended)
5. A method for recovering substantially all carbon dioxide generated in a combustion process according to claim 1,
characterised in that
the air stream is heated by heat exchanging with ~~not~~ exhaust gas generated in at least one combuster.

6. A method for recovering substantially all carbon dioxide generated in a combustion process according to claim 1,
characterised in that
the air stream, before being heated, is compressed and divided into several streams and each stream is heated in a heat exchanger located between two membrane stages.

(Amended)
7. ~~Use of the~~ a method according to claim 1, for generating heat and power.

(amended)
8. ~~Use of the exhaust gas recovered by the~~ A method according to claim 1, wherein the exhaust gas is applied for enhanced oil recovery or for injection in a geological formation.

(amended)
9. ~~Use of the exhaust gas recovered by the~~ a method according to claim 1, wherein the exhaust gas is applied in a chemical process to make carbon containing products.

(Amended)
10. ~~Use of heated air generated by the~~ A method according to claim 1, ~~forgenerating~~ wherein heated air generated by the method is applied for generating pure oxygen in a mixed conducting membrane.

(Amended)

11. ~~Use of heated air generated by the~~ a method according to claim 1, wherein heated air generated by the method is applied for generating synthesis gas consisting of one or more of the components CO, CO_2, H_2 and N_2 or for generating heat in a mixed conducting membrane reactor where the membrane reactor is capable of reacting a mixture of steam and a carbon containing fuel with oxygen permeated through the said membrane to make synthesis gas and/or heat.